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SPACE 2009

ABSTRACT: With more than 50 years of achievements, the U.S. space industry has an unparalleled record of success ranging from landing on the moon to providing telecom access to the remote reaches of the world. However, the glamour of this industry has gone beyond the notion of "Rocket Science" to that of a competitive, investment based, growth industry with an expectation of business, technology, and process innovation. The time of technology innovation solely supported by government expenditures, as was the case with expeditions to the moon and the reusable space shuttle program, have long given way to satellite system technologies that provide demand-based goods and services for commercial consumers, civil agencies, and governments alike. The overall U.S. space industry is healthy today. Especially encouraging are areas of innovation related to space launch, operationally responsive space, and space tourism. This Space Industry Study Report examines the current state of the U.S. Space Industry, its challenges, an outlook of the future, and the role of government. It also makes several recommendations to U.S. space policy, to education, and for industry.

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INTRODUCTION

In 1962, John F. Kennedy ignited a surge of innovation and national will by declaring, "We choose to go to the moon in this decade…putting a man on the moon as part of a great national effort of the United States of America." In 2009, as we celebrate the 40th anniversary of the fulfillment of that vision, it is appropriate to pause and reflect on how far we have come and where we hope to go in the future. It is fitting to ask the hard questions: Has this nation lost its will to lead the global community in space? Is this nation prepared to exercise true leadership – and risk-taking – in the pursuit of this responsibility? What must we do to reassert that will to innovate and to reach for the stars?

The space industry is a critical element of strategic importance to the future of this planet and for those who venture to assume or retain a leadership role in it. It is with this in mind that the ICAF Class of 2009 Space Industry Study sought to understand and evaluate the state of the space industry in this nation and around the world. This report will provide perspectives regarding the nature and condition of the current space industry environment, the challenges facing us, and the outlook for the industry. Finally, it will assess the goals and roles of government in the future, and summarize a number of specific topics of significant interest to the space community in a series of brief essays.

Overall, we assess the U.S. space industry to be healthy today. Especially encouraging are areas of innovation related to space launch, operationally responsive space, and space tourism. Although the United States remains the world's leading space power, this preeminence is not assured over the long-term due to weaknesses associated with policy, education, and launch infrastructure. It is our hope that this nation will continue to place appropriate emphasis on its leadership role in space, and to apply appropriate resources to ensure U.S. viability in this industry in the future.

THE INDUSTRY DEFINED

The space industry consists of a fairly well defined set of core elements – launch, satellite, and control – supporting a wide range of users, including commercial, civil, government, and military customers. These essentials, combined with a healthy measure of innovation and international competition, characterize today's environment.

The launch element consists of a handful of rocket and engine manufacturers who provide the means to propel payloads into orbit and beyond, as well as the facilities required to conduct the launches themselves. These elements—the rocket and the facility—may or may not be provided by the same entity.

The satellite element consists of a similarly small number of satellite and space vehicle manufacturers. In this realm, "buses" serve as basic platforms, providing propulsion, electric power, and other physical support for a wide variety of payloads, such as communications, imagery, research, or military applications. A wider range of industry participants is capable of designing and building these payloads, though integration of the entire satellite—bus, payload, and sometimes launch vehicle—is limited to relatively few providers. In addition to satellites, payloads may also consist of human-habitable spacecraft, space station components, or exploratory vehicles such as Mars-exploring rovers.

Once in orbit – or on their way to other worlds beyond Earth's orbit – satellites and space vehicles must communicate with ground stations on Earth. The third element, namely the

control function, consists of ground stations, which provide system monitoring and control of the actual spacecraft, as well as distribution of data to users on the ground.

Space industry customers include commercial, civil, and national security entities. Pure commercial users include companies engaged in telecommunications, imaging, and related ventures (e.g., cell-phone and internet providers, entertainment companies such as XM Radio and DirecTV, and satellite imagery providers supporting applications like Google Earth). Civil usage includes space exploration and research endeavors (predominantly National Aeronautics and Space Administration [NASA] - and National Oceanic and Atmospheric Administration [NOAA]-driven), as well as weather and climate prediction. National security space interests include intelligence, surveillance, and reconnaissance (ISR); secure communications; and position, navigation, and timing (PNT). Interestingly, PNT now ties military usage of space inextricably to the commercial sector, which has become heavily dependent on the Global Positioning System (GPS) constellation.

In recent years, new companies intent on making space more affordable and accessible have challenged the established space community. Companies such as SpaceX and Sea Launch have aggressively taken on the launch function, seeking efficiencies and aiming to cut launch costs by at least half. In addition, the concept of space tourism is spurring creativity in the design of new spacecraft, with innovators such as Scaled Composites and XCOR challenging the status quo. Even on the military end of the scale, paradigm shifts are occurring under the banner of Operationally Responsive Space (ORS), where pressure for a radical change in approach may ultimately transform the space industry.

An added dimension, affecting the industry across the board, is the emergence of strong international competition and cooperation. The European Union (EU) has become a major player, while Russia continues to compete strongly for space launch business. China, too, is emerging as a strong competitor in the space arena, along with a host of other international participants. This intersection of evolving core elements, a varied and expanding user community, and expanding international participation define the essential characteristics of the U.S. space industry today.

CURRENT CONDITIONS

For the past two years, the space industry has had global revenues totaling over $250B, of which government expenditures represented 31 percent, with the remainder consisting of commercial goods and services.[1] The $175B commercial system revenue stream is roughly split 97 percent into services value system, 2 percent into satellites, and 1 percent for launch.[2] Within the $170B services sector, commercial satellite operations infrastructure represented nearly 20 percent of total revenue. This infrastructure is comprised of terminals, satellite control ground stations, terrestrial network infrastructure, and other terrestrial based elements. Satellite-based communications services are the single largest commercial satellite-industry value system, providing high-value services to both government and commercial consumers. The estimate of international and U.S. government consumption of commercial satellite services within this sector was approximately $3.7B ($1.7B from the U.S. alone), representing approximately 22 percent of total revenue for these applications of the value chain. Demand for commercial earth observation and remote sensing has increased steadily over the last several years, though at $7.3B it remains the smallest application-based value system. This demand, nearly 40%, has come from commercial applications for weather forecasting and imaging providers such as Google Earth while additional demand from government customers such as the National

Geospatial Intelligence Agency make up less than 10%.[3] Position, navigation and timing (PNT) systems are a special case within commercial satellite applications, since launch and satellite costs are not included in the value system, as they are provided exclusively through government expenditures. The remaining elements of the navigation value system represent 21 percent of the entire worldwide space economy and 32 percent of commercial satellite applications revenue.[4] The remainder of the current conditions section will explore the U.S. elements of the space industry.

Satellite Development

For the U.S. spacecraft manufacturing market, the defense industrial base has emerged from the consolidation prompted by the end of the Cold War that resulted in three major players: Boeing, Lockheed-Martin, and Northrop Grumman. Additionally, several smaller companies are working to make inroads into niche markets within the spacecraft manufacturing and integration market segment, including Orbital Sciences, Raytheon, General Dynamics, Ball Aerospace, and LORAL. The U.S. spacecraft manufacturing market is characterized by a predominance of government spending, fluctuating commercial demand, and highly concentrated suppliers.[5] Certain more mature sub-segments such as geostationary communications satellites, with very predictable satellite service life models, are not as volatile but have some excess capacity. The more diverse non-geostationary market segment, consisting of remote sensing, communications, and several other applications, is also subject to volatility and shifting demand.[6] Following an initial surge in launches in the late 1990s, the market experienced a steep drop-off in 1999 as it encountered significant competition from terrestrial markets.

In general, market shares between satellite manufacturers can appear to change markedly from year to year due to the extremely high per-unit cost of satellites, ranging from hundreds of millions to billions of dollars each. This high degree of change does not necessarily reflect market volatility, however. The prevalence of government contracts with long lead times and forecasted requirements within the mature segments of the U.S. satellite manufacturing industry render it somewhat recession resistant. Of possibly greater impact to the industry is uncertainty caused by annual or biennial budgets, which introduces the constant risk of potential cuts or procurement delays.

Additional uncertainty is created by the present need to dedicate federal spending to economic recovery stimulus actions. The President's 2010 budget increases NASA funding from $17.6B to $18.7B, and earmarks $1B in separate stimulus-related allocations for a net increase of $2.1B. The current plan addresses the Space Shuttle retirement and provides continued U.S. access to the International Space Station via the yet-to-be-delivered Orion Crew Exploration Vehicle.

Launch Services

The U.S. space launch services sector serves several different markets, ranging from commercial telecommunications systems, to unique and complex military or scientific systems requiring huge boost systems and associated architectures, to manned systems such as the Space Shuttle, which require the unique resources of NASA to put into orbit. Many launches today, particularly in heavy lift (over 25,000 kg), are not currently performed by U.S. launch companies. The current U.S. heavy launch is provided by the Atlas 5 and Delta IV systems operated by the Boeing/Lockheed-Martin launch consortium, United Launch Alliance, and in the future by SpaceX's Falcon 9. Medium lift capability is a niche presently occupied in the United States primarily by the Delta II, which is nearing retirement, and Orbital's Taurus 2, despite not yet having demonstrated the reliability of the legacy Delta rockets.

CHALLENGES

The U.S. space industry, like all enterprises, has endured cyclical periods of growth and contraction. The collapse of global financial markets in 2008; the increase in political tensions in the Middle East, Southwest Asia, and with Russia; and the fact that commercial space revenue has outpaced expenditures from U.S. national space, exacerbated by a high level of risk aversion among Congress and the American people, have combined to create many challenges impacting the U.S. space industry's growth potential.

Education

The future health of the domestic space industry relies heavily on the U.S. educational system for needed human capital. The lack of support for math and science disciplines within the secondary school system in the United States has resulted in the U.S. graduation rate in engineering and hard sciences from U.S. colleges falling short of anticipated industry requirements.[7] Additionally, there has been a severe degradation of Department of Defense in-house engineering and technical expertise, resulting in a potentially unhealthy reliance on non-governmental entities in support of national security requirements. To redress this shortfall, government and industry should provide internships, fellowship programs, and job opportunities to foster an environment of continual academic and economic growth.[8]

International Competition

China, India, Russia and European nations have made significant progress in recent years, and their space programs provide tremendous benefits. Careful management of space program relationships between the United States and Russia as well as the emerging space agencies have potential high payoffs in terms of the continued development of free market space with full political and diplomatic benefits. As the global marketplace encourages additional countries to compete and collaborate, new partnerships will result in potential political, military, economic, and diplomatic benefits and/or concerns. For example, the United States and China have a limited history of both civilian and military collaboration in space. Mistrust of Chinese space intentions grew in the mid-1990s amidst accusations of U.S. companies transferring potentially sensitive military information to China.[9] Cooperation has since stagnated due to increased economic, political, and security frictions in the U.S.-China relationship.[10] Similarly, Russia's August 2008 invasion of Georgia, and their abrupt interruption of critical oil and natural gas supplies to Europe and Australia, have spurred discussion as to whether it might be in the United States' best interests to extend the Space Shuttle program, and/or accelerate the Constellation replacement program rather than rely on Russian transport as the sole means of manned transport to the ISS over the next several years. As these concerns indicate, although international space cooperation has the potential to provide significant benefits in financial efficiencies, programmatic and political sustainability, and workforce stability to the U.S. national space program, it also carries the risks associated with interdependence in any national security endeavor.

Space Situational Awareness (SSA)

An area the United States could lead the development of international partnerships is that of Space Situational Awareness (SSA). However, there are numerous challenges preventing the realization of true SSA, including:

- an increasing population of space objects that can threaten active satellites,
- the inability to differentiate between failures caused by unintentional events and those resulting from intentional hostile action,
- hardware and manufacturing technology limitations, and
- appropriateness of sharing range and depth of data between international partners.

Currently, only periodic detection and tracking can be accomplished by the Space Surveillance Network (SSN) due to limited sensors, human resources, and computing capacity.[11] As a result, the SSN uses a task-based approach to detection and tracking. Sensor tasking is based on predicted satellite orbits and on previously collected data in a space catalog.[12] Inadequate sensor performance, especially for the characterization of objects in geosynchronous orbit, further exacerbates this issue. Additionally, it is often difficult or impossible to achieve the greater level of awareness required to determine the cause of satellite anomalies on-orbit.

Launch Services

The U.S. portion of the launch market continues to erode while the overall global demand for launch services increases. There is evidence that demand erosion in U.S. launch is due to instability of the value chain created by unpredictable demand, new vehicles, new competitors outside the United States, and overall lower flyaway prices from international competitors, particularly Russia.[13] For example, an important concern with the Operationally Responsive Space (ORS) concept is coordination of range assets leading up to launch. Cape Canaveral Air Force Station personnel indicate that it takes up to two years to plan and execute a launch under normal conditions.[14] However, ORS requires assembly and launch within days or weeks. Creating the requisite launch facilities and procedures to facilitate such a schedule is prohibitive: "Space is an expensive business. The cost to establish a new [launch] capability…is likely to be in the multi-billion dollar range."[15] Once established, the cost of transportation itself is high—about $12,000-$30,000 per kilogram, depending on the launch system—providing a significant incentive on the part of consumers to find cheaper alternatives (such as UAVs) to space.

Shuttle Replacement

The replacement for the Space Shuttle—the Orion launch system—required for U.S. manned launch beyond 2010 relies on as yet unproven technology. Several new concepts will require vetting since the Orion differs from its predecessors—the Apollo Program and the Space Shuttle. First, it will not use fuel cells for power, but will instead use solar arrays like the International Space Station (ISS).[16] Second, the use of solid rocket booster technology as the sole method of propulsion also remains immature (as applied to manned flight) and may potentially delay development.

International Traffic in Arms Regulations (ITAR)

The U.S. government controls the export of sensitive technologies and components that might put our national security at risk. Explicit to the space industry, the government restricts the export of

launch vehicles, spacecraft, component technologies, and other space-related items. U.S. companies maintain that the advent of ITAR is the proximate cause of their loss of market share, but a survey of export control impacts conducted by the Institute for Defense Analysis (IDA) on behalf of the Deputy Undersecretary of Defense for Industrial Policy maintains that this loss was consistent with the general trend, given the depressed demand and new entrants to the market.[17] A 2003 Center for Strategic and International Studies report focusing on similar data as the IDA report found, however, that inefficient administration of the ITAR process by the Department of State was at least partially to blame.[18] Additionally, there is an overwhelming perception from industry that the current ITAR U.S. Munitions List (USML) is too broad and includes a range and depth of technology that does not reflect advances in technology or foreign availability[19]—many listed defense articles and services are now commercial commodities. ITAR encourages our allies to develop indigenous space capabilities and industries at the expense of U.S. market share.[20]

OUTLOOK

Reforming the Space Interagency Framework

Government institutions controlling policy for national security, civil, and commercial space have not always coordinated effectively to further the strategic aims of the United States. Differences in priorities and shifts in emphasis have led, over the years, to a vacillating institutional architecture with overlaps in some cases and gaps in others. There is general discontent, both in and out of government, with current national strategy and the lack of integration of national security, civil, and commercial space policy. To better integrate the government's policies, initiatives, and overarching strategy regarding the space medium, the Administration should reestablish and empower a National Space Council (NASC) as the primary U.S. national space policy integrator and arbiter. The President's call for a new NASC is encouraging, but execution details will ultimately determine whether such reforms are effective or lasting.

Operationally Responsive Space

There has been much discussion about ORS—a concept based primarily on the need for two capabilities: rapid reconstitution of existing satellite capabilities and the ability to provide tailored satellite support to commanders in the field.[21] Currently projected ORS funding will provide for little more than development of processes, procedures, and standards.[22] The ORS roadmap includes plans for an operational unit by 2015. However, former U.S. Strategic Command deputy commander, Lt. General Robert Kehler, has expressed a desire to reach this milestone sooner.[23] It seems unlikely that any significant capability can be made available appreciably sooner. However, accelerated establishment of operational units may serve as a forcing function to speed development and finalization of concepts. The greatest area of concern for ORS is a culture of risk aversion. At a declared success rate of 80 percent for ORS launches, there is a large potential for backlash if and when the anticipated 20 percent failure rate comes to fruition.

International Cooperation

International space cooperation has the potential to provide significant benefits to the U.S. national space program. These benefits will be short lived, however, if space exploration is approached as an individual national endeavor. Since the Apollo Program, our focus has been on

low earth orbit—the Space Shuttle Program and the ISS—and unmanned space exploration. Foreign space programs have made significant progress and provide tremendous potential new capabilities. With careful management, these relationships can have high political and diplomatic payoffs, and facilitate continued exploration of space. In order to realize these benefits, the United States must aggressively pursue cooperative space exploitation and other space-related initiatives with the international community through a well developed strategic framework that provides guidance in legal, economic, and technical responsibilities and controls. This cooperation will allow the United States to continue promoting international and commercial partnerships in exploration while furthering U.S. scientific, economic, and national security interests.

An example of international and commercial partnerships in space is the emerging domain of space tourism. Industry leaders have positioned themselves to provide customers with space packages using reusable suborbital launch vehicles. Reusable suborbital launch vehicles will be a key enabler to driving down the total costs currently associated with space travel. Evolution in the space industry is producing platforms and launch systems at lower costs making space tourism reachable to a broader range of consumers. Commercial space tourism is quickly becoming a possibility for enthusiasts who also want to view the earth from space at a more reasonable cost.

Weaponization of Space

Space, like air, land, and sea, is a medium ripe for conflict and exploitation. Although a policy debate over whether space has been militarized is ongoing, the 2007 anti-satellite test by the Chinese and the U.S. shoot-down of a crippled intelligence satellite make the case that space is already weaponized. The U.S. military, as well as commercial and civil markets, are increasingly reliant on space capabilities, therefore space-based asset vulnerability must be considered in the development of national policy. The United States must proceed with a balanced policy of watchful preparedness, protecting our critical space assets while considering how its actions are viewed by other nations. Aggressive acts to destroy satellites would be catastrophic—not only to the owner of the destroyed capability, but also by adding hazardous space debris—and detrimental to the interests of the major players in space. The United States must lead the international community in promoting the peaceful use of space and in the proactive monitoring of space activity. But our reliance on space capabilities mandates that above all, the United States must remain vigilant.

Space Logistics

Logistics are as crucial in space operations as in all other military and economic spheres. Cargo movement (heavy lift launch; on-orbit warehousing and assembly; and on-orbit repair, refueling, retrieval, capture, and return capabilities) requires continued development to support future manned space flight, as well as existing on-orbit satellites. Examples of ongoing efforts include the European Automated Transfer Vehicle (ATV) to deliver cargo and remove waste from the International Space Station, as well as Orbital Satellite Systems' planned SMART Orbital Life Extension Vehicle (SMART-OLEV) system to extend service life and maneuver aging on-orbit satellites. Moreover, national security, civil, and commercial space organizations must also move forward with the more mundane, but equally important, space logistics initiatives such as standardized interfaces on satellites, robotically accessible refueling ports, remote docking and tether capabilities, satellite retrieval and towing, "plug-and-play" quick-

connects, easy accessibility and modular replacement for failed and aging components, and self-retaining fasteners and latches. These capabilities, though often overlooked in discussions of space sustainability, are required if we are to retain our leadership in space exploitation.

GOVERNMENT ROLE AND IMPACTS

Despite increasing commercialization, space remains dependent on government oversight and often patronage to create an environment conducive to its growth and exploitation. Across the spectrum of space activities—national security, civil, and commercial—the government has developed institutions, policies, and regulations to encourage, manage, and develop the space medium in the interests of the United States first and then the world. However, these institutions have not always worked in concert with each other, and efforts to coordinate their activities have not produced cohesive strategies to further the strategic aims of the United States.

International Traffic in Arms Regulations

At the intersection of the space industrial base and the government's national space policy resides the ITAR export regime managed by the Department of State. The entry of European competitors Alcatel and EADS into the previously U.S.-dominated satellite market in the mid-1990s coincided with the shift from the Department of Commerce's Commerce Control List (CCL) to ITAR.[24] A general loss of market share amongst U.S. manufacturers from 68 percent to 58 percent ensued.[25] Since that time, the State Department has worked to accelerate export approvals while industry has developed the practices necessary to work within ITAR constraints. Despite concerns that ITAR would curtail U.S. business, in fact the Canadian firm TELSAT was the only major customer cited as permanently switching from U.S. component providers as a result of ITAR. At the same time, ITAR has become effective at barring foreign competition from the U.S. defense market. While prime contractors seem to have overcome the most negative effects of ITAR and sometimes even cloak themselves in its protective shield for domestic work, small tier suppliers without the resources and experience to wade through ITAR still face challenges in the international market.

Space Policy

In domestic space policy, the government's role as patron and purchaser of space capabilities continues to be important but is troublesome in certain areas, such as workforce expertise. In national security space, for example, the government's science and technology workforce has largely lost the ability to actually "build" systems. The trend of outsourcing many non-core functions that began in the mid-1990s initiated a process later furthered by the Joint Capabilities Integration and Development System (JCIDS) reforms and the aging of the space-experienced workforce. JCIDS has effectively outsourced half of the requirements definition process for space, as the government no longer possesses personnel with the technical knowledge.[26] As a result, JCIDS now creates "greatest common factor" requirements definitions as a byproduct of consensus among the large number of government stakeholders. All these factors have impacted the government's ability to be a smart consumer of space.

The U.S. government is also the key player in how and when America partners internationally to explore and exploit space. U.S. space policy states that the government will pursue, as appropriate and consistent with U.S. national security interests, international cooperation with foreign nations and/or consortia on space activities that are of mutual benefit and that further the peaceful exploration and use of space, as well as to advance national security,

homeland security, and foreign policy objectives. Areas for potential international cooperation include, but are not limited to, space exploration, space surveillance information consistent with security, U.S. national security and foreign policy interests, and the development of Earth observation systems.[27] Questions remain, however, regarding who should take the lead in developing new policies and creating a revised strategic framework that emphasizes the importance of international space cooperation while protecting our national security.

There is today no single government body to coordinate and integrate policies, regulations, and investments across the government's space portfolio. This was not always the case. When the Office of the President had a NASC empowered to establish and integrate policy across government agencies and departments, it proved to be a potentially successful model. However, its existence ran counter to some Presidents' organizational philosophies, or proved ineffective at developing an integrated policy accepted across the several U.S. space communities during various periods.[28] These failings point to key shortcomings in previous attempts at an effective NASC-run interagency process—inconsistent presidential support and improper staffing. While the incoming administration supports the re-establishment of a NASC, proper staffing is critical to its success as a policy coordinator, integrator, and driver.

Space Law

While the U.S. government has long championed the commercialization of space in the interests of the nation and its economy, it now faces a non-traditional entry into the space sector—space tourism. The emergence of the space tourism market has forced the government to develop legal and regulatory requirements for the commercial human space industry. The Commercial Space Launch Amendments Act of 2004 was passed to promote the development of the emerging human space flight market.[29] The Federal Aviation Administration (FAA) was designated the executive agent overseeing licensing and safety requirements. The law was primarily designed to ensure passenger safety on suborbital space flights while limiting liability.[30] Also, to keep insurance costs low, the act makes liability indemnification inapplicable to space flight.[31] This protects the industry from some law suits in the event of an unfortunate incident.[32] The act currently prohibits imposing regulatory requirements on crew and passengers before 2012.[33] As the space tourism market matures, the FAA and the legal community will revaluate these regulations to enhance future safety requirements and liabilities for the space tourism industry.

Almost every use of space has legal, commercial and security ramifications.[34] Space law is of "paramount importance to international, regional, and national efforts to further develop space activities and to increase knowledge of the legal framework,"[35] yet the U.S. government and the legal community have not kept up or invested in the legal framework of space. The space tourism case and the 2004 Congressional action highlight the sometimes stop-gap approach that exists across the broad range of space law. Problems continue to increase as private and public commercial companies grow impatient with lethargic, governmental bureaucracies. The Committee on the Peaceful Uses of Outer Space (COPUOS) legal subcommittee is of the opinion "that certainty in the application of space law would encourage Member States to accede to the United Nations treaties on outer space".[36] While many stakeholders are committed to reaping the benefits of operating in and exploring space, industry and intergovernmental organizations have not made the effort to ensure the foundations of space law are properly established. Furthermore, these complications and undefined boundaries create potentially detrimental effects against which America and other nations frame their national security strategy and defensive posture. In the end, the U.S. government lacks a holistic approach to space law.

ESSAYS ON MAJOR ISSUES

ESSAY 1: The Challenge of Achieving Space Situational Awareness

On February 10, 2009, an active Iridium spacecraft and a retired Russian communications satellite collided. As a result, both spacecraft were destroyed and a significant amount of debris was produced.[37] In September 2008, the newest Defense Support Program (DSP) satellite began an uncontrolled drift through the geosynchronous belt.[38] These two recent events illustrate the critical need for accurate and persistent detection and tracking capabilities, and highlight a significant shortfall in the United States' Space Situational Awareness (SSA) capabilities. The ability to detect, track, and characterize space objects and events is a prerequisite for effective SSA, yet current U.S. systems provide only rudimentary space surveillance capabilities. While new SSA systems are on the cusp of being deployed, there will remain a significant gap between needs and actual capabilities for the foreseeable future unless additional investments are made. This essay will briefly review U.S. SSA capabilities and describe challenges associated with achieving appropriate SSA.

Current Capabilities

Multiple ground-based sensors make up the Space Surveillance Network (SSN), which provides limited SSA capabilities,[39] however, present U.S. capabilities are more focused on *surveillance* than *situational awareness.* The SSN is only capable of periodic tracking of objects due to the limited number of sensors. Only objects greater than approximately 10 cm can be regularly detected and tracked in the space objects catalog.[40] The network contains three types of sensors: dedicated, collateral, and contributing. Sensors are considered *dedicated* when their primary purpose is space surveillance, which is conducted under the control of U.S. Strategic Command (USSTRATCOM). These sensors detect and track objects both in "near-Earth" orbit, which extends to approximately 6,000 km, and in "deep space," which extends from approximately 4,800 km to beyond the geosynchronous belt. Other USSTRATCOM sensors are *collateral* SSN assets because they have a primary purpose other than space surveillance but also have inherent surveillance capabilities that are leveraged on a not-to-interfere basis. The current set of collateral SSN sensors can only detect and track objects in near-Earth orbit. *Contributing* sensors are not under the control of USSTRATCOM, but provide limited near-Earth and deep space detection and tracking,[41] along with limited characterization of deep space objects.[42]

Challenges of Achieving Space Situational Awareness

Challenges to achieving SSA include: (1) an increasing population of space objects, including debris, that can threaten active satellites, (2) the inability to differentiate between failures caused by unintentional events and those that are the result of intentional hostile action, and (3) demanding detection, tracking, and characterization requirements leveraged by the Department of Defense (DoD) and the National Aeronautics and Space Administration (NASA).

Increasing Population of Objects in Space

The number of man-made objects in orbit has increased significantly over the last decade. In 1997, the SSN routinely tracked approximately 8,000 objects.[43] Today, the network tracks approximately 18,000 objects.[44] Because the SSN supports only periodic detection and tracking, the detection of new objects and the tracking of existing objects is a challenge due to limited

sensors, human resources, and computing capacity.[45] As a result, the SSN uses a task-based approach to detection and tracking in which sensors are tasked to look for objects where they are predicted to be based on previously collected data.[46] Consequently, the SSN has a difficult time detecting and tracking new items, or objects that change orbit between observations.

Differentiating Between Natural and Man-Made Effects

When a satellite fails on-orbit, one of the most significant challenges is determining the cause of failure. Sources of information external to the spacecraft are often necessary to identify why a satellite failed. This could be detection and tracking data provided by ground-based radars or telescopes that might indicate if an object collided with the satellite, or was acted upon by some terrestrial system. Characterization data such as images from optical sensors can indicate if the satellite is tumbling out of control, but it is often impossible to achieve this level of awareness due to inadequate sensor performance. The inability to differentiate between types of failures has significant implications, since unintentional failures are unfortunate events, but failure caused by a hostile act potentially represents an act of war.

Demanding DoD and NASA Requirements

NASA has a requirement for DoD to be able to detect and track "objects that are 1 centimeter and larger, in low-earth orbit, and with perigees 600 kilometers or less."[47] NASA has also requested that DoD notify NASA of orbital breakups within one hour of occurrence.[48] DoD needs drive characterization requirements, but its focus is on detection and tracking of non-cooperative targets, especially in geosynchronous orbit. DoD also needs to understand and predict the purpose, status, intent, and actions of satellites, which is accomplished through characterization. Satisfying this set of requirements represents a significant challenge in terms of technology and affordability.[49]

Conclusion

With the population of space objects increasing at a significant rate and the inability to differentiate a hostile attack from an unintentional failure, the need for SSA has never been greater. Yet, the United States does not possess an effective SSA capability due to a lack of sustained investment. Achieving SSA requires the capacity to not only persistently detect and track space objects in a timely manner, but also to characterize high interest objects. The limited number of ground-based sensors, especially with high resolution performance, the lack of space-based sensors, and the fact that the United States does not routinely take advantage of non-traditional sources of SSA are all factors that constrain the ability of the U.S. to achieve situational awareness in space.

Author: CDR John Hood, USN

ESSAY 2: The State of U.S. Space Launch Capabilities

Astronaut Buzz Aldrin once said, "our destiny in space has always been inextricably linked to our launch vehicles."[50] Yet barriers to commercial development, exacerbated by unreliable government funding, have resulted in a U.S. launch sector that struggles to compete in a global environment. To resolve these capability shortfalls, the U.S. should adopt a comprehensive policy that includes longer-term budgets for civil space programs to assure reliable payload funding streams, greater policy and regulation latitude, and a target architecture

focused on recapitalized infrastructure, greater modularity, and standardized interfaces and protocols to support diverse payload requirements.

Challenges and Opportunities

Despite the continued and arguably growing need for launch services, the U.S. launch capability is not commensurate with either its reliance on space services or its traditional role in global technological leadership. When the Space Shuttle flies its last mission in 2010, the United States will rely on Russia for manned space lift until NASA's Ares I comes online years later. Meanwhile, China, India, and Japan aggressively pursue manned and unmanned space capabilities, and Europe's EADS Astrium, which now owns Surrey Satellite Technology, Ltd, is currently the world's leader in small, rapid satellite manufacture.[51] Although the United States continues to maintain a significant share of the global market, it has not invested sufficiently to offset the national and quasi-governmental commitments of its global rivals.

As Christenson and Pober observe, "Space is an expensive business. The cost to establish a new [launch] capability…is likely to be in the multi-billion dollar range."[52] And once established, lift itself is costly—about $12,000-30,000 per kilogram, depending on launch system. "Many in the industry characterize this high cost of transportation…as the primary economic barrier [to making] new space business activities financially feasible."[53] Even SpaceX, which strives to cut the cost of reliable access to space by a factor of ten[54] relies on US military infrastructure, leased at a nominal rate, to stay in business.

Japan is also committed to breaking the cost barrier—with an elevator. Formerly the stuff of science fiction, space elevator technology is finally nearing feasibility through advances in high-strength, low mass carbon nanotube technology. Estimates vary, but analysts suggest that a single space elevator could lift two million kilograms per year[55] at $500-$1,600 per kilogram,[56] making space and microgravity manufacturing suddenly accessible to an array of players. Japan is focused on aggressively beginning construction in 2018,[57] viewing space elevator technology as a key national economic interest and a stepping stone to future orbital industries. The US evinces no similar commitment, even given that an elevator's comparative cost advantage if successful could enable control of up to 95% of the global launch market[58]—with significant impact to our national aerospace industrial base, as well as commercial interests and revenues.

Even with national-level commitment, however, launch would remain high-risk—both technically and financially. The finely tuned physics of payload distribution, weather, orbital insertion, and recovery/reuse constraints, have thus far precluded economies of scale, at least in the vehicle segment. Further, hundreds of millions of dollars of payload can be destroyed in a single failed launch (launches have historically failed at about a 2% rate[59]—a significant risk with payloads that are extremely expensive and often unique, with long developmental lead-times) risking future business as well as liability costs.

Despite these challenges, the space launch industry remains strong enough to continue to attract would-be players. Global demand for communications, imagery, and PNT systems will continue to drive the market, as other nations attempt to launch their own satellites and alleviate their dependence on U.S. systems. In addition, long-lead scientific observation platforms assure several years of known launch requirements.[60] Finally, many on-orbit assets are nearing the end of their life-cycles, or are facing pressure from improved technologies. These factors will continue to contribute to the multi-year backlogs that assure the future of existing firms like Orbital Sciences, SpaceX, Boeing, Lockheed-Martin, and Northrop Grumman.

Even more important to the light/medium lift segments in the United States, however,

may be the DoD's pursuit of "operationally responsive space" on-demand launch of small satellites to support warfighter requirements for dedicated communications and imagery in near-real-time. One longer term possibility is outlined in *SpaceLift 2025*, an Air Force document that envisions a ground-launched spaceplane-like vehicle. Another would be an equatorial electro-magnetic rail gun launcher such as the one the U.S. Navy is developing. Such a system would be potentially capable of immediate launch of small payloads (1250 kilograms or less) for as little as $600 per kilogram.[61] These initiatives, however, are at least a decade from fruition, leaving hopefuls focused on providers like Orbital Sciences and SpaceX to achieve the rapid, light launch capability ORS demands.

Policy Recommendations

J.A. Vedda, Center for Space Policy and Strategy, notes that it is "the long-held position of the executive and legislative branches that the success of the U.S. commercial launch industry is in the national interest, and that it is appropriate for government to encourage and facilitate an internationally competitive industry."[62] Toward this end, several recommendations are offered.

First, the U.S. must ensure long-term, adequate, and predictable funding streams. As previously noted, space launch is expensive—the more so when anticipated launch revenues are lost to payload delays resulting from multi-year programs being repeatedly segmented or cut. Recapitalization of launch facilities—to include commercial assets—should be a high national priority, as they support high-tech jobs, as well as long-term strength in navigation, imaging, scientific observation and experiment, and microgravity manufacturing. Research and development also requires stable funding streams to attract top scientific and engineering talent, which must itself be fostered through increased focus on science, technology, and mathematics in the U.S. secondary and post-secondary education system.

Second, the United States should ease unduly restrictive government regulation impacting the space launch sector. Technology import/export restrictions should be carefully tailored to maximize supply chain flexibility for components that are readily available on the global market without incurring security risks. Policies restricting U.S. systems from "piggy-backing" with foreign commercial systems with which they do not actually interact also prevent industry from maximizing existing launch capacity. Further, regulations that prohibit lobbying by government entities should be reexamined to enable this crucial and complex industry to articulate and defend what often appear to the public to be inordinate timelines, costs, and risks.

Finally, the United States should define a national space launch architecture to foster interoperability and economies of scale for industry participants. In addition to outlining a way ahead for infrastructure modernization, such an architecture should define a preference for payload and launch vehicle modularity where possible in order to reduce risk, facilitate on-orbit repair or replacement; increase survivability in the event of attack, collision, or other catastrophic event; and increase launch flexibility. In order to support these goals, the target architecture should define standard communication and interface protocols and security standards to facilitate networking between distributed components and payload/launch vehicle interoperability.

Conclusion

Space remains "the ultimate high ground." Even as it implements these launch policies, the United States should actively pursue "game-changing" technologies, such as a space elevator, that could radically change space transport, as well as present tremendous opportunities for spin-off technologies. Although the public appetite for such high-risk initiatives is at a near-historic low, they are critical to retaining U.S. pre-eminence in space, and in sustaining the high-tech

industries and global economic leadership with which space access is inextricably entwined.

Author: Lt Col Cynthia Wright, USAF

ESSAY 3: Human Capital – The DoD's Loss of Technical Personnel

The end of the Cold War and corresponding military draw-down of the 1990s brought with it great concern about cutting too deep and creating a "hollow" force. Across the military services, there was an effort to minimize logistics "tail" activities in order to preserve funding and maintain as much warfighting "tooth" capability as possible. At the end of nearly two decades of this trend, the DoD finds itself with insufficient in-house engineering and technical expertise to design, build, and field space based and other technically innovative systems in a timely, cost effective manner.

Technical Outsourcing

"Since 1955, the executive branch has encouraged federal agencies to obtain commercially available goods and services from the private sector when the agencies determined that such action was cost-effective."[63] Although the Office of Management and Budget (OMB) formalized this policy in its Circular A-76 in 1966, it was not until the post Cold War draw-down in the mid-1990's that Congress and the executive branch began to place significant emphasis on achieving greater economies and efficiencies in operations.[64] This drive to optimize "tooth to tail" ratios while cutting costs, led to an across-the-board effort to identify both civilian and military positions as either "inherently governmental" or not in order to identify candidate positions for outsourcing. One casualty of this process proved was a large portion of the DoD's science and technology positions. The New York Times reports that in the Air Force alone, "the number of civilian and uniformed engineers on the core acquisition staff has fallen 35 to 40 percent in the past 14 years."[65] Closure of several Army Software Development Centers throughout the 1990s is an indicator that the Air Force is not alone in this reduction.

Of the science & technology billets that remain in the DoD, many positions are now filled by workers who have become highly skilled at interpreting regulation, policy, security, and testing requirements for supporting contractors but often lack systems engineering, design, and development skills. Exacerbating the problem, the Joint Capability Integration and Development System (JCIDS), intended to help eliminate Service-specific acquisitions by identifying desired capabilities rather than defining systems, in fact resulted in a process that produces overly broad requirements. Without experienced development engineers to refine these capabilities requirements into system requirements, JCIDS-approved documents often result in "grande-design" contracts with severely ill-defined technical scope.

Conclusion

Although the current situation took over 15 years to evolve, correcting the engineering and technical shortage should begin immediately. First, the DoD should continue recent efforts to revitalize systems engineering as a discipline. The government cannot afford to leave engineering decisions solely in the hands of contractors, but rather needs to ensure it has in-house technical expertise in key acquisition and oversight positions. In order to achieve this, the DoD should enact policies to encourage both engineering graduates and mid-level engineers from commercial industry to enter government service. Finally, the DoD should re-visit the JCIDS process to require the originators of capabilities-based requirements work closely with

Program Managers to refine end-state requirements. Ideally, this will ensure an engineering scope that enables requirements to be put on contract with much better cost, performance, and schedule accuracy and transparency.

Author: LTC Thomas "Pat" Flanders, USA

ESSAY 4: Operationally Responsive Space: A Transformational Vision

Operationally Responsive Space (ORS) is a transformational concept in support of the DoD space community, where time-critical needs are addressed in timeframes which were unimaginable to the space industry of the past. In matters of days or weeks, rather than years, payloads may be placed in orbit. Innovative ideas currently being refined at the ORS Program Office may actually bring about a revolution in space launch thought. However, there are significant challenges to be overcome, including the viability of a risk-taking approach in a seriously risk-averse nation.

The ORS Program Office was created in mid-2007, and reports to the Executive Agent for Space, with requirements oversight from the Commander, USSTRATCOM. While the ORS office is quickly learning its role and developing capabilities, it is nonetheless a young and developing enterprise attempting to implement novel ideas.

ORS Strategy

The ORS strategy is based on a three-tier approach. Tier-1 utilizes capabilities from existing satellites, in hours-to-days timeframes. Tier-2 consists of rapid assembly, integration, testing, and deployment of a small, low cost satellite, in days-to-weeks. Tier-3 involves rapid development of a new capability in the months-to-one-year timeframe. In building up its concept of operations (CONOPS) from current to future state, the ORS Office has embarked on a multi-pronged approach which is intended to meet current needs while creating building blocks for future full operational capability. These activities are 1) to respond to existing urgent needs, 2) create ORS enablers (innovative concepts), and 3) to develop authorities, doctrine, command relationships and CONOPS to accommodate the new business model.[66]

Innovation

One area of innovation is the development of a new range and launch control concept. ORS plans to assemble and launch within *days or weeks*. Rather than using fixed range assets, ORS will utilize a *space-based range* paradigm.[67] This may include a GPS-based tracking system, which does not require ground-based radar or other tracking instrumentation. Further, through the use of prequalified trajectories and autonomous on-board range safety systems, ORS eliminates the need for resource-intensive range assets.[68]

Another component of this streamlined approach is rapid integration of satellites and launch systems utilizing a "plug and play" concept, then to employ a Transporter Erector Launcher (TEL), capable of launching the integrated rocket without transfer of the system to a secondary launch structure. ORS will also seek to automate the mission data load process, shortening this time from 30 days to a matter of hours.[69]

However, ORS is, by design, taking on a significant element of risk in order to be "responsive," and has repeatedly declared its expectation of an 80% success rate.[70] It is not clear however, if Congress or other leadership will accept such a level of failure. It is not difficult to

visualize ORS cancellation with a 20% mission failure rate. The ORS Office should seriously evaluate the consequences of such failures prior to irrevocable commitment to this arrangement and develop commensurate risk mitigation strategies.

Conclusion

ORS is a transformational concept whose time has come. Significant progress has been made in the development of new ideas – particularly the accelerated launch concept. While not all questions are completely answered, there is reason to believe they can and will be addressed. The transformational nature of ORS is of key importance to the entire space industry – providing a vision of the possibilities for changing the way we think about space launch. However, it is not without issues and risks. The one area that presents the most concern for ORS is American risk aversion. At a declared success rate of 80% for ORS launches, there is a large unknown potential backlash if and when the 20% failure rate becomes a reality.

Mr. Wayne B. Osborn, DAF

ESSAY 5: Weaponization of Space

Space plays an extraordinary and increasingly important role in U.S. national security and as an enabler of our National Military Strategy. The military relies heavily on space assets for navigation, signals intelligence, communications, and imaging. The commercial market, while contributing to an industrial-based global economic order, is just as important to the military with satellite services providing global communications, television broadcasting, weather forecasting, and ship, aircraft, and vehicle navigation. U.S. policy on space begs a delicate balance to allow free military and commercial access while protecting our vulnerable space assets that are ripe for exploitation.

Weaponized and Militarized Space

There is much debate whether the United States should be prepared for space warfare to protect its assets against such nations as Iran, North Korea, and China. The 2007 anti-satellite test by the Chinese and the Operation Burnt Frost in 2008, argues the point that space is already militarized and weaponized. President Obama, during his campaign, pledged a ban on space weapons. His proposed tenants to an international, cooperative approach to space security are negotiating agreements on "Rules of the Road" for acceptable behavior, opposing weaponization of space, and protecting American's space assets. An international space treaty should address an active weapons-free space environment, minimization of orbital debris, environmental accountability, passive use of military assets, and prohibition on disruption of passive space assets.

Eisenhower's visionary decision to establish the National Aeronautics and Space Administration (NASA) in 1958 brought a commonplace peace strategy. Obama's overarching objectives of promoting international cooperation and keeping space secure amplifies the Eisenhower policies. Bruce DeBlois, a retired Air Force officer and an adjunct fellow of the Council on Foreign Relations, favors the Eisenhower policy of space as a sanctuary and contends that space is militarized but not weaponized.[71] DeBlois submits that those who support space sanctuary policies believe that unilateral hegemony in space would ultimately undermine national security and be destabilizing the international environment.[72] He supports diplomatic efforts for treaties and agreements, reduction on dependence on a small number of critical and vulnerable space systems, development of passive protective measures, and maintaining

technical capabilities for retaliation if the need arises.[73] He presents a valid argument that scientific and technological strength provides a strong bargaining chip in international diplomacy, commerce, and politics.[74]

Current United States Policy

The U.S. National Space Policy released in 2006 was criticized by many experts citing that President Bush was too hard-line and that a strategic shift toward a more military-oriented, unilateral approach to space, "could begin an arms race leading to catastrophic space warfare."[75] Although the Bush policy had the same central theme as the 1996 Clinton policy, it differs by dismissing the rights of other space powers, is actively hostile to collective security, and no longer regards space as a cooperative environment.[76] His administration's intent was to deploy missile defense systems with the capability of shooting down intercontinental-range ballistic missiles within reach of the low Earth orbit.[77] Then Secretary of Defense, Donald Rumsfeld, maintained, "that the United States has been so derelict in not arming space that it is vulnerable to a potential Space Pearl Harbor."[78] Echoing the Rumsfeld position was the U.S. Space Command's Vision for 2020, a plan is for "counter space operations…" whose two principal themes are, "… dominating space medium and integrating space power throughout military operations."[79] These are strong offensive and defensive statements which can be interpreted by other nations as ominous threats.

Dr. John L. Remo, a physicist and a research associate at the Harvard-Smithsonian Center for Astrophysics suggests that the 1972 Anti-Ballistic Missile Treaty between the United States and Russia is an appropriate framework in which to outlaw space weapons.[80] By prohibiting the deployment of a full-scale missile defense system the likelihood of a nuclear war was lessened. Likewise, a prohibition on space based weapons would have the same objective. He further suggests incentives for sharing of space technologies, enhancing launch reliability, and limiting orbital debris.[81]

Shaping Future U.S. Policy

We must secure the "Commons of Space" as we would the environment and oceans. Space should not become another theater for an arms race such as land, air, and the seas. The United States must consider how its actions are viewed and reacted to by other nations as potential enemies may deploy space-based weapons of their own. Aggressive acts to destroy satellites would be catastrophic in adding to space debris and detrimental to the best interests of the major players in space. A space race would otherwise consume intellectual resources and scarce capital.

President Obama should therefore rescind the Bush era policy and adopt one which would strike a balance between peace and security. His administration should place emphasis on diplomacy using scientific and technology sharing as leverage. With his leadership, the public must be educated on the implications of the U.S. dependence on space assets (military, civil, and commercial implications) and realize the vulnerabilities.

With technical advances and increased potential threats from developing nations, our strategy must now be balanced. The United States must take the lead as a world power to guide the international community toward preservation of a peaceful space and continue to be the lead in stewardship of monitoring space activity. The United States must concurrently invest in space weapons research and development of space weapons to balance potential offensive capabilities in protection of its spaced-based assets. The United States must remain vigilant.

Ms. Kathleen Callahan, Dept of Army

CONCLUSION AND RECOMMENDATIONS

Despite reports in the popular press, this assessment found the current space industry fairly healthy in all sectors including space, launch, and control, with significant areas in which innovation is thriving. The effect of the current economic crisis represents the most significant unknown. Based on the assessment of the challenges facing the industry and the outlook for the future, the following recommendations are offered for consideration.

Recommendations for U.S. Space Policy

- ***Establish an effective interagency process to address space issues.*** The current interagency process results in confusion and poorly integrated policy. Consideration should be given to reestablishing a Space Council chartered to implement a truly integrated national space policy. Consistent presidential-level support and proper staffing are essential ingredients.
- ***Update U.S. Space Policy.*** The Administration's space policy should clearly assert that the space industry is critical to U.S. national security, and promote the position that the launch and satellite sectors must remain competitive in the global marketplace. A new policy should also recognize that militarization of space does not imply that the weaponization of space is inevitable. We must secure the "Commons of Space" as we would the environment and oceans, striking a balance between peace and security.
- ***Maintain support for NASA's space exploration programs.*** As the leading space-faring nation in the world, it is important to maintain support for NASA's exploration and human spaceflight programs. Combined, these programs represent significant potential for innovation and provide benefits for humankind by pushing the envelope of technology and knowledge. The resulting advances migrate from the space industry to the general public and commercial sectors, with benefits across a broad spectrum of sciences and industries.
- ***Increase international space cooperation.*** International cooperation in space has the potential to provide significant benefits to the U.S. national space program in the form of fiscal and programmatic efficiencies, political sustainability, and workforce stability. The U.S should aggressively pursue cooperative space exploitation and other space related initiatives with the international community. An important part of this effort includes creating, in cooperation with international legal bodies, effective and integrated policies to regulate space activities.[82]

Recommendations to Address Export Control Issues

- ***Retain ITAR under the Department of State (DoS), but provide DoD a greater voice in the decision process***. Consider granting DoD additional authority and responsibility with respect to development, collaboration, and sale of relevant products and information. Any impediments to the U.S. space industry that may impede the industry from competing in the global market must be closely reviewed for efficacy in terms of consequences of those policies for U.S. national security.
- ***Expedite ITAR license reviews***. Increase the number of DoS licensing officers. Increase the dollar thresholds for Congressional review to cut processing timelines. Maintain a database of previously licensed articles and services to enable fast track approval authority for subsequent export actions.
- ***Complete a biannual USML update***. Submit to Congress and DoS for legislative and regulatory action to identify space related commodities that are readily available

commercially to allow U.S. corporations to compete more effectively in the international market.

Recommendations to Improve Education

- ***Expand support for groups and programs that promote science, technology, engineering, and mathematics (STEM) investments related to the space industry.*** These groups include the Space Foundation and the STEM Education Coalition. These groups enable teacher professional development, provide incentives for students to obtain STEM degrees and pursue technical careers, and promote diversity in the STEM workforce.[83]
- ***Form closer ties between the U.S. national space program and space-related education, especially at the primary and secondary school levels.*** The 2003 Workshop on the Future of Space Education states. "There needs to be a robust link between the educational community (i.e. the primary and secondary schools as well as colleges and universities) and a well-defined space research and exploration agenda that is strongly supported by the space industry, NASA, and other relevant U.S. governmental agencies." We must make space exciting again, a career that our children aspire to, and work to achieve as adults.[84]

Recommendations to Improve U.S. Space Industry Capabilities

- ***Address space manufacturing issues as part of acquisition reform.*** Unattainable schedule and performance milestones, a loss of capacity in government management and oversight, and a lack of capacity of the space industrial base to meet future requirements are key elements in need of reform and revitalization for the spacecraft manufacturing industry.
- ***Give greater consideration to logistics when designing space systems.*** Logistics is a frequently overlooked aspect of our future success in space. Future exploration and utilization of space will hinge on major advances in cargo movement, including heavy lift launch; standardized interfaces, on-orbit warehousing and assembly; and on-orbit repair, refueling, retrieval, capture, and return capabilities.
- ***Promote an environment where innovative concepts can prosper.*** Two "game-changing" areas in particular should be nurtured—ORS concepts and space tourism. Together these two areas represent significant potential for innovation and the opening of completely new markets for the U.S. space industry. We must not let the risk-averse nature of government-sponsored space acquisition strangle ORS in its infancy.

Recommendations to Improve Space Launch Capabilities

- ***Adequately fund the recapitalization and modernization of launch facilities.*** These aging facilities provide not only current high-technology jobs, but also long-term economic competitiveness through the exploitation of access to space.
- ***Actively pursue "game-changing" technologies that could radically affect space transport.*** One such technology might be the space elevator, which would not only allow a near-monopoly on affordable space access to the first nation to acquire it, but also present tremendous opportunities for spin-off technologies, such as new composite materials, as well as microgravity manufacturing of crystals, metals, and pharmaceuticals that are prohibitively expensive to make on Earth.
- ***Define a national space launch architecture that will foster interoperability and economies of scale.*** Such an architecture should define a preference for launch vehicle and, where possible, payload modularity to facilitate on-orbit repair/replacement; improve catastrophic

event survivability; and increase launch flexibility. The target architecture should also define standard communication/interface protocols and security standards to facilitate networking between distributed components and interoperability of payloads and launch vehicles.

Recommendations to Improve Space Industry Human Capital

- ***Address significant shortfalls in government human capital.*** Revitalize engineering as a discipline in the DoD, and provide incentives to recruit highly experienced engineers from industry.
- ***Provide incentives for small- to medium-size companies to play a larger role in the defense space industry.*** Expanding the number of players will foster competition and innovation.

Recommendations to Improve Space Situational Awareness Capabilities

- ***Continue critical investments in sensors for detection and tracking.*** Investments in detection and tracking capability, especially of small objects, should be given the highest priority. Without the ability to detect and track objects of interest, characterization cannot be accomplished. Adequately funding and implementing SSA capabilities should be a national priority for the United States since the lack of SSA places every satellite in orbit at risk.
- ***Leverage non-traditional sources for characterization.*** An all-source approach should be taken to address the characterization challenge, to include open and human sources. Addressing DoD characterization requirements requires leveraging existing intelligence and sensor capabilities that are not currently considered part of the SSN.
- ***Improve and expand the sharing of SSA data*** All satellite operators collect health and status information on the spacecraft they operate, but that data is not routinely shared today. Sharing this data would enable greater awareness of cooperative space objects and free up resources to focus on non-cooperative objects.

With the election of the new administration, America as a unique opportunity to address enduring challenges related to the space industry, many of which potentially endanger our national security. Many of these recommendations would require significant funding to implement, implying a rebalancing of national security priorities and associated investments. However, many others require little or no significant additional funding, particularly in the areas of policy and export controls. In all cases however, significant willpower and commitment will be required to tackle these issues.

In closing, while the space industry as a whole is healthy at this time, the nation must ensure that the industry continues to grow through business, technology, and process innovation. As detailed in this report, the United States remains the world's leading space power but this preeminence is not assured over the long-term. Our recommendations placed emphasis on issues that affect policy, education, and launch infrastructure. In the end, it is our hope that this nation will continue to place appropriate emphasis on its leadership role in space, and to apply appropriate resources to ensure U.S. viability in this industry in the future.

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